NRL – OUR HERITAGE

Today, when government and science seem inextricably linked, when virtually no one questions the dependence of national defense on the excellence of national technical capabilities, it is noteworthy that in-house defense research is relatively new in our Nation's history. The Naval Research Laboratory (NRL), the first modern research institution created within the United States Navy, began operations in 1923.

Thomas Edison's Vision: The first step came in May 1915, a time when Americans were deeply worried about the great European war. Thomas Edison, when asked by a *New York Times* correspondent to comment on the conflict, argued that the Nation should look to science. "The Government," he proposed in a published interview, "should maintain a great research laboratory....In this could be developed...all the technique of military and naval progression without any vast expense." Secretary of the Navy Josephus Daniels seized the opportunity created by Edison's public comments to enlist Edison's support. He agreed to serve as the head of a new body of civilian experts—the Naval Consulting Board—to advise the Navy on science and technology. The Board's most ambitious plan was the creation of a modern research facility for the Navy. Congress allocated $1.5 million for the institution in 1916, but wartime delays and disagreements within the Naval Consulting Board postponed construction until 1920.

The Laboratory's two original divisions—Radio and Sound—pioneered in the fields of high-frequency radio and underwater sound propagation. They produced communications equipment, direction-finding devices, sonar sets, and perhaps most significant of all, the first practical radar equipment built in this country. They also performed basic research, participating, for example, in the discovery and early exploration of the ionosphere. Moreover, the Laboratory was able to work gradually toward its goal of becoming a broadly based research facility. By the beginning of World War II, five new divisions had been added: Physical Optics, Chemistry, Metallurgy, Mechanics and Electricity, and Internal Communications.

The War Years and Growth: Total employment at the Laboratory jumped from 396 in 1941 to 4400 in 1946, expenditures from $1.7 million to $13.7 million, the number of buildings from 23 to 67, and the number of projects from 200 to about 900. During WWII, scientific activities necessarily were concentrated almost entirely on applied research. New electronics equipment—radio, radar, sonar—was developed. Countermeasures were devised. New lubricants were produced, as were antifouling paints, luminous identification tapes, and a sea marker to help save survivors of disasters at sea. A thermal diffusion process was conceived and used to supply some of the ^{235}U isotope needed for one of the first atomic bombs. Also, many new devices that developed from booming wartime industry were type tested and then certified as reliable for the Fleet.

NRL Reorganizes for Peace: Because of the major scientific accomplishments of the war years, the United States emerged into the postwar era determined to consolidate its wartime gains in science and technology and to preserve the working relationship between its armed forces and the scientific community. While the Navy was establishing its Office of Naval Research (ONR) as a liaison with and supporter of basic and applied scientific research, it was also encouraging NRL to broaden its scope and become, in effect, its corporate research laboratory. There was a transfer of NRL to the administrative oversight of ONR and a parallel shift of the Laboratory's research emphasis to one of long-range basic and applied investigation in a broad range of the physical sciences.

However, rapid expansion during the war had left NRL improperly structured to address long-term Navy requirements. One major task—neither easily nor rapidly accomplished—was that of reshaping and coordinating research. This was achieved by transforming a group of largely autonomous scientific divisions into a unified institution with a clear mission and a fully coordinated research program. The first attempt at reorganization vested power in an executive committee composed of all the division superintendents. This committee was impracticably large, so in 1949, a civilian director of research was named and given full authority over the program. Positions for associate directors were added in 1954.

The Breadth of NRL: During the years since the war, the areas of study at the Laboratory have included basic research concerning the Navy's environments of Earth, sea, sky, and space. Investigations have ranged widely—from monitoring the Sun's behavior to analyzing marine atmospheric conditions to measuring parameters of the deep oceans. Detection and communication capabilities have benefitted by research that has exploited new portions of the electromagnetic spectrum, extended ranges to outer space, and provided a means of transferring information reliably and securely, even through massive jamming. Submarine habitability, lubricants, shipbuilding materials, firefighting, and the study of sound in the sea have remained steadfast concerns, to which have been added recent explorations within the fields of virtual reality, superconductivity, and biomolecular science and engineering.

The Laboratory has pioneered naval research into space from atmospheric probes with captured V-2 rockets through direction of the *Vanguard* project—America's first satellite program—to inventing and developing the first satellite prototypes of the Global Positioning System. Today NRL is the Navy's lead laboratory in space systems research, fire research, tactical electronic warfare, microelectronic devices, and artificial intelligence.

The consolidation in 1992 of NRL and the Naval Oceanographic and Atmospheric Research Laboratory, with centers at Bay St. Louis, Mississippi, and Monterey, California, added critical new strengths to the Laboratory. NRL now is additionally the lead Navy center for research in ocean and atmospheric sciences, with special strengths in physical oceanography, marine geosciences, ocean acoustics, marine meteorology, and remote oceanic and atmospheric sensing. The expanded Laboratory is focusing its research efforts on new Navy strategic interests and needs in the post-Cold War world. Although not abandoning its interests in blue-water operations and research, the Navy is also focusing on defending American interests in the world's littoral regions. NRL scientists and engineers are working to give the Navy the special knowledge and capabilities it needs to operate in these waters.

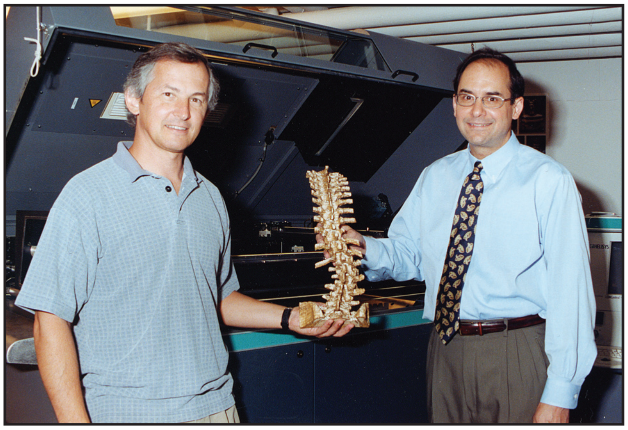
2001 IN REVIEW

In the last year Naval Research Laboratory researchers have been active across a wide spectrum of research areas. In a new organizational undertaking, NRL established a laboratory Institute for Nanoscience. The new institute will conduct nanoscale multidisciplinary research at the intersections of the fields of material science, electronics, and biology. Researchers will attempt to hybridize current research in the several disciplines to produce scientific breakthroughs and technological innovations of use to the warfighting community.

In other new Laboratory initiatives, Electra, a high energy repetitively pulsed krypton fluoride laser, came on-line this year. The new laser is a critical element of a Department of Energy funded program to develop technologies for fusion energy and defense applications. The Electra, with a laser output of 400 to 700 joules, will be used in compressing and then heating fuel pellets to produce energy. It will serve as a laboratory-scale test model for the technologies critical to establishing laser-based fusion energy. Electra will help develop the knowledge base necessary for scaling up the laser fusion process into a practical industrial working level.

This year saw the launch of NRL Space Science Division's J-PEX instrument for collecting (for the first time) a high-resolution spectrum of a white dwarf star at extreme ultraviolet wavelengths. The Joint Astrophysical Plasmadynamic Experiment was a collaborative undertaking of NRL, Lawrence Livermore National Laboratory, and the University of Leicester and Mullard Space Science Laboratory in the U.K. The primary J-PEX instrument is a high-resolution spectrometer capable of making extreme ultraviolet measurements in the 225 to 245 angstrom range. Besides providing new information on the chemical composition of white dwarf stars, which are the end product of the evolutionary life cycle of stars in our galaxy, the mission will serve as a testbed for innovations in spectrometer technologies. The latter include improved spherical diffraction gratings and high-reflectance coatings.

Researchers at NRL have collaborated with doctors from the National Naval Medical Center (NNMC) to create a full-scale model of a human spine. Using NRL's Helisys Laminated Object Manufacturing System (LOMS), the NRL researchers created a very detailed anatomical model of a spine with severe



Mr. Roy Rayne and Dr. James Thomas, from NRL's Multifunctional Materials Branch, display their full scale model of the human spine.

scoliosis. The model was used by the NNMC doctors in preparing for surgery. Besides providing greater detail than available from other means, the LOMS model possessed the advantages of providing excellent contrast on detailed skeletal features and an appearance and texture closer to actual bone. The fabrication method computationally slices a computer representation of the spine into thin contour layers about the horizontal plane. The model then is created by bonding together multiple layers of paper, each with a unique laser-cut outline corresponding to spinal material boundary. The paper layers are subsequently bonded together. The NRL researchers and Navy doctors plan to follow up this collaborative effort with a meeting to explore joint research in which NRL would use its scientific modeling expertise to aid the National Naval Medical Center doctors in their neurological-related research.

NRL researchers also perfected a number of systems directed at aiding the nation's operational military forces. Dragon Eye, a new robotic airborne sensor built and demonstrated by Laboratory personnel, was made available for production prototyping. The technology includes a 4-pound glider that fits in a backpack, has the radar signature of a bird, includes a video eye, and can be assembled and launched in less than 5 minutes. It is a low-priced, easily transportable aerial reconnaissance system made with commercial, off-the-shelf materials that are easily replaceable. Dragon Eye allows the military field operator to see what is happening around him from a bird's eye view.

The first real-time hyperspectral target detection system flown aboard a Predator unmanned air vehicle was demonstrated this last year. The demonstration project, called Wide Area Reconnaissance Hyperspectral Overhead Real-Time Surveillance Experiment (WAR HORSE), consists of a nadir-looking visible hyperspectral sensor that produces data analyzed by an on-board real-time processor. A high-resolution image is collected from a boresighted panchromatic visible sensor. A three-band false-color waterfall display of hyperspectral data with overlaid target cues, along with corresponding high-resolution image chips, is transmitted to a ground station in real time via a digital data link. The typical flight parameters for the Predator carrier are an altitude of 10,000 feet and an airspeed of 70 knots.

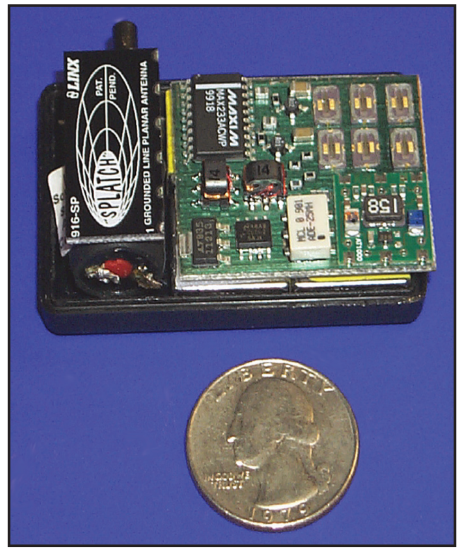
In a collaborative undertaking with private industry, NRL scientists demonstrated the Navy's Shared Reconnaissance Pod (SHARP) technology. SHARP includes dual mode electro-optical and infrared cameras and sensor packages that can be suited to both long-range (45 nautical miles) and medium-range (15 nautical miles) uses. The new sensor technology will help pilots locate targets that are moved or hidden by an enemy. SHARP provides military operators with a "real-time" tool to locate, identify, and strike enemy targets. The technology will be used in the Navy's new F/A-18E/F fighter and other aircraft.

Computer scientists at NRL have developed a wearable 3-D system that gives warfighters in the field real-time information about their operating environment. The system, named the Battlefield Augmented Reality System (BARS), gives users a "heads-up" display. The user wears a see-through head-mounted display through which he or she can see the real world. Computer-generated graphics and text are overlaid atop the real world in the display. BARS consists of two main components: the Wearable Augmented Reality System (WARS) and the 3-D Interactive Command Environment (3DICE). WARS is carried by the user in the field. It is a self-contained backpack system, which includes the wearable computer, tracking system, see-through head-mounted display, interaction devices, and a transceiver for wireless communication. The operator uses the WARS to receive reports and orders from the 3DICE and can enter simple situation reports by speaking, gesturing, or using a personal digital assistant. Those using the 3DICE may be hundreds or thousands of miles from the area of action. Using information garnered from WARS users and other sources, the command constructs a tactical picture of the environment and transmits orders to operators in the field.

This year the Naval Center for Space Technology announced the successful design, development, qualification, launch, and operation of a state-of-the art Miniature Space Ground Link System (SGLS) Transponder for use on future advanced and miniature spacecraft. The U.S. Air Force's MightySat II.1 satellite became the first spacecraft to launch and use the new transponder. The SGLS Transponder represents the smallest such full-featured space qualified system ever designed and flown. It weighs only 3.3 lbs., with a total volume of 90 cubic inches. This represents a 70% reduction in volume and mass over existing systems. The transponder provides a satellite with Department of Defense (DOD) standard Air Force Satellite Control Network S-Band secure spacecraft telemetry, tracking, and command services. The transponder, along with NRL-designed miniature antennas, diplexers, cables, and couplers, represent enabling radio frequency technology for next-generation DOD miniature spacecraft.

NRL is proud of its record of transitioning the results of its research to the operational Navy as well as to the private sector. At last count, over 100 products were on the commercial market for sale under license from NRL. NRL's technology licensing program accounted for over two-thirds of the Navy's royalty income in FY 2001.

NRL's success at transitioning technology to the Fleet was recognized in September of 2001 with the Vice Admiral Harold G. Bowen Award for Patented Inventions. The Bowen Award singles out a patented invention that has had a significant impact on the operation of the Navy as measured by the extent of adoption for Navy use and cost savings, increased military capability, and/or increased quality of life of Navy personnel. NRL Chemistry Division scientists Dennis R. Hardy, Erna J. Beal, and Jack C. Burnett invented a method for assessing distillate fuel stability that has reduced the number of incidents in which Navy vessels have shut down or failed to achieve full power due to contaminants in fuel that result from chemical reactions that take place in the fuels while they are stored for extended periods of time. Since being adopted into MIL-SPEC 16884J for bulk procurement of all shipboard distillate fuel, the NRL fuel assessment method has saved the Navy over $100 million in replacement fuel, filtering, and clean-up costs, as well as increased operational readiness and combat readiness. In addition, the method has been adopted as an American Society for the Testing of Materials (ASTM) standard.



NRL's small-scale, low-power Surface Acoustic Wave (SAW) chemical agent detector capable of real-time detection in the parts per billion range. Built-in telemetry relays data to a remote processor. This technology is being evaluated for detection of various hazardous and toxic agents.

NRL's achievements in technology transfer to the private sector were also recognized with awards in 2001. In May of 2001, NRL received four Federal Laboratory Consortium (FLC) Awards for Excellence in Technology Transfer, the maximum number of awards that may be given to a single laboratory. Drs. Jerry Meyer, Craig Hoffman, Filbert Bartoli, and Igor Vurgaftman of the NRL Optical Sciences Division received one of the four awards for their successful transfer of the Quantum Mobility Spectrum Analysis (QMSA) technology to Lake Shore Cryotronics. Under license from NRL, Lake Shore sells instrumentation for electronic transport measurements for process control to semiconductor manufacturers and researchers.

A second FLC Award for Excellence in Technology Transfer was presented to Dr. John Reintjes, Dr. John Tucker, Dr. Abraham Schultz, Mr. Jefferson Willey, Ms. Amy O'Brien (all of the NRL Optical Sciences Division), Prof. Lawrence Tankersley (U.S. Naval Academy), Mr. Paul Howard (P.L. Howard Enterprise, Inc.), Prof. Chao Lu (Towson University), and Mr. Scott Thomas (American Communication Systems), in recognition of their successful transition of the LaserNet Fines technology both to the operational Navy and to commercial production. LaserNet Fines is an all-optical method for monitoring and analyzing wear debris in engine lubricating fluid. Developed initially for the Navy to enhance condition-based maintenance programs, LaserNet Fines is now sold commercially by Lockheed Martin under license from NRL.

Mr. Vincent Park, of NRL's Information Technology Division, was awarded the third FLC Award in recognition of his participation in the transfer of the Temporally-Ordered Routing Algorithm (TORA). TORA supports the extension of Internet-type services to users on the move or in remote locations. Mr. Park pursued standardization of protocol by participating in the Internet Engineering Task Force (IETF) and TORA is now sold under license from NRL as an option for the NovaRoam 900, a wireless router product manufactured by Nova Engineering, Inc.

The final FLC Award for Excellence in Technology Transfer was presented to Drs. Richard Colton, David Kidwell, Gil Lee, David Baselt, and John-Bruce Green of the NRL Chemistry Division. The group was recognized for the development and transfer of biosensor technology based on atomic force microscopy (AFM) that is capable of detecting and characterizing single biomolecules, including DNA, viruses, and bacteria. The technology was originally conceived for detection of biological warfare agents, but it has a broad range of potential commercial applications that are currently being exploited.

NRL TODAY

ORGANIZATION AND ADMINISTRATION

The Naval Research Laboratory is a field command under the Chief of Naval Research, who reports to the Secretary of the Navy via the Assistant Secretary of the Navy for Research, Development and Acquisition.

Heading the Laboratory with joint responsibilities are CAPT Douglas H. Rau, USN, Commanding Officer, and Dr. Eric Hartwig, Director of Research (acting). Line authority passes from the Commanding Officer and the Director of Research to three Associate Directors of Research, a Director of the Naval Center for Space Technology, and an Associate Director for Business Operations. Research divisions are organized under the following functional directorates:

- Systems
- Materials Science and Component Technology
- Ocean and Atmospheric Science and Technology
- Naval Center for Space Technology.

NRL operates as a Navy Working Capital Fund (NWCF). All costs, including overhead, are charged to various research projects. Funding in FY 01 came from the Chief of Naval Research, the Naval Systems Commands, and other Navy sources; government agencies, such as the U.S. Air Force, the Defense Advanced Research Projects Agency, the Department of Energy, and the National Aeronautics and Space Administration; and several nongovernment activities.

PERSONNEL DEVELOPMENT

At the end of FY 01, NRL employed 2981 persons—42 officers, 104 enlisted, and 2835 civilians. In the research staff, there are 812 employees with doctorate degrees, 339 with masters degrees, and 466 with bachelors degrees. The support staff assists the research staff by providing administrative, computer-aided design, machining, fabrication, electronic construction, publication and imaging, personnel development, information retrieval, large mainframe computer support, and contracting and supply management services.

Opportunities for higher education and other professional training for NRL employees are available through several programs offered by the Employee Development Branch. These programs provide for graduate work leading to advanced degrees, advanced training, college course work, short courses, continuing education, and career counseling. Graduate students, in certain cases, may use their NRL research for thesis material.

For non-NRL employees, several postdoctoral research programs exist. There are also agreements with several universities for student opportunities under the Student Career Experience Program (formerly known as Cooperative Education), as well as summer and part-time employment programs. Summer and interchange programs for college faculty members, professional consultants, and employees of other government agencies are also available.

NRL has active chapters of Women in Science and Engineering, Sigma Xi, Toastmasters International, Federally Employed Women, and the Federal Executive and Professional Association. Three com-

NRL main site, located off Interstate 295 in S.W. Washington, D.C., as viewed from the Potomac River.

puter clubs meet regularly—NRL Microcomputer User's Group, NeXT, and Sun NRL Users Group. An amateur radio club, a drama group (the Showboaters), and several sports clubs are also active. NRL has a Recreation Club that provides basketball and softball leagues and swim, sauna, whirlpool bath, gymnasium, and weight-room facilities. The Recreation Club also offers classes in martial arts, aerobics, swimming, and water walking.

The Community Outreach Program traditionally has used its extensive resources to foster programs that provide benefits to students and other community citizens. Volunteer employees assist with and judge science fairs, give lectures, and serve as tutors, mentors, coaches, and classroom resource teachers. The program also sponsors African American History Month art and essay contests for local schools, student tours of NRL, a student Toastmasters Youth Leadership Program, an annual holiday party for neighborhood children in December, and a book donation program for both students and teachers. Through the Community Outreach Program, NRL has active partnerships with four District of Columbia, three Aberdeen, Maryland, and three Calvert County, Maryland, public schools.

NRL has an active, growing Credit Union. Since its creation in 1946, NRL Federal Credit Union (NRL FCU) has grown to about $250 million in assets and serves about 22,000 NRL employees, contractors, select employee groups, and their families. NRL FCU is a leader in providing innovative financial services such as a dynamic home page and Online Access (Internet home banking) with bill payer. Focusing on the credit union philosophy of *People Helping People*, NRL FCU offers a wide array of no-fee services plus financial education and assistance. NRL FCU is a full service financial institution providing various mortgage programs and creative lending services. Debuting in 2001, NRL FCU Financial Services, LLC, a wholly owned subsidiary of NRL Federal Credit Union, offers full service investment and brokerage services. For information about membership or any financial service, call (301) 839-8400 or click www.nrlfcu.org.

Public transportation to NRL is provided by Metrobus. Metrorail service is three miles away.

For more information, see the *NRL Review* chapter, "Programs for Professional Development."

SCIENTIFIC FACILITIES

In addition to its Washington, D.C. campus of about 130 acres and 102 main buildings, NRL maintains 11 other research sites, including a vessel for fire research and a Flight Support Detachment. The many diverse scientific and technological research and support facilities are described in the following paragraphs.

RESEARCH FACILITIES

Radar

NRL has gained worldwide renown as the "birthplace of radar" and, for a half-century, has maintained its reputation as a leading center for radar-related research and development. A number of facilities managed by NRL's Radar Division continue to contribute to this reputation.

A widely used major facility is the Compact Antenna Range (operated jointly with the Space Systems Development Department) for antenna design and development, as well as radar cross section measurements. The range is capable of simulating farfield conditions from 1 to 110 GHz with a quiet zone of approximately 7 ft in diameter and 8 ft in length. Instrumentation covers from 1 to 95 GHz. Another strong division capability is in the Computational Electromagnetics (CEM) Facility, which has capabilities for complex electromagnetic modeling, including radar target and antenna structures. The Radar Signature Calculation Facility within this group produces detailed computations of radar cross sections of various targets, primarily ships. The CEM facility includes multiple-CPU supercomputers that are also used to design phased array radar antennas. There is tremendous synergism between the CEM group and the Compact Range Facility. This provides the ability to design in the CEM environment, test in the compact, and have immediate feedback between the theoretical and experimental aspects to shorten the development cycle for new designs.

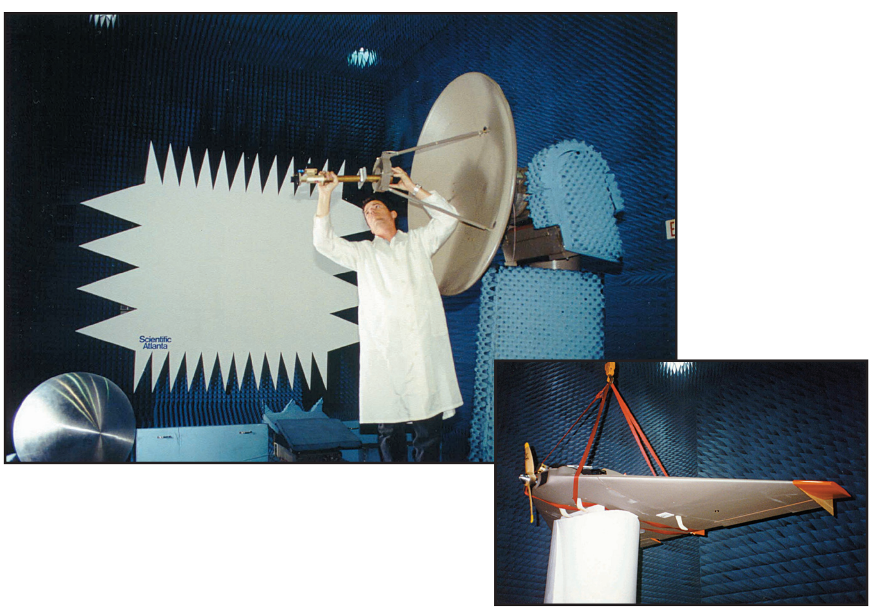
In connection with airborne radar, the division operates a supercomputer-based Radar Imaging Facility and an inverse synthetic aperture radar (ISAR) deployed either in the air, on the ground, or aboard ship for radar-imaging data collection. A P-3 aircraft equipped with the AN/APS-145 radar and cooperative engagement capability is also available for mounting experiments.

In connection with ship-based radar, the division operates a Radar Test Bed Facility at the Chesapeake Bay Detachment (CBD), Randle Cliffs, Maryland. Represented are radars for long-range air search, point defense, and surface search functions. The point defense radar, with its large (4 ft × 8 ft) X-band phased array antenna, and the AN/SPQ-9B ADM systems are designed to be mobile so that testing is not limited to this specific environment.

Other installations operated by the division include an Electromagnetic Compatibility (EMC) Facility supported by a mode-stirred chamber, and a Computer-aided Engineering (CAE) Facility. The microwave microscope, a high-resolution (2-cm) capability for investigating backscatter from both surface and volumetric clutter, is now operational, and a millimeter-wave radar system operating in the 94 GHz region is currently being developed. The division provides direct technical support and has direct access to data from the AN/TPS-71, the Navy's relocatable over-the-horizon radars. Concepts and engineering developments in connection with target identification are explored by using an experimental Cooperative Aircraft Identification system.

Information Technology

The Information Technology Division (ITD) is at the forefront of DOD research and development in artificial intelligence, telecommunications, computer networking, human-computer interaction, informa-



A view of the interior of the compact range, with the primary reflector in the background. In the foreground, an antenna assembly is being readied for testing on the range positioner, while the inset photo shows a small unmanned aerial vehicle as it undergoes radar cross section measurements.

The 128-processor Silicon Graphics Origin3800 system, currently with 128 Mbytes of RAM, the first production unit in the world with R14000 processors, was brought on-line in mid FY 01. The NRL Center for Computational Science, as a Distributed Center of the DOD High Performance Computing Modernization Program, provides such systems (at no cost) for anyone approved by the Program Office.

tion security, parallel computation, and computer science.

The division maintains local area computer networks to support its research and hosts testbeds for advanced high-performance fiber-optic network research. These networks make available hundreds of high-performance computers to local and remote users. The ITD research networks connect to NRL's internal network via high-speed links ranging from DS-3 (45 Mbps) links on NASA Science Internet (NSI); to OC-12c (622 Mbps) on DREN/S-DREN; to OC-48c (2.4 Gbps) on ATDnet. The ATDnet is a metropolitan ATM network that supports advanced network research at OC-48c speeds and higher; other major partners include the National Aeronautics and Space Administration, the National Security Agency, the Defense Information Systems Agency, the Defense Advanced Research Projects Agency, and the Defense Intelligence Security Agency. Research on ATDnet includes introduction and testing of new networking protocols; wave division multiplexing to greatly increase network capacity; and the evolution to all-optical networks, with switching at the optical layer. Research on the high-end computational assets and networks results in close association with applications that demand these leading-edge capabilities and has allowed ITD to achieve significant results in a number of areas. These include current efforts in pushing the state of the art in motion imagery with progressive scan in high-definition TV (HDTV) where 1.5 Gbps data streams are needed to handle the raw output. The Motion Imagery Laboratory (MIL) continues at the leading edge of technology to provide the environment for experiments in the convergence of the progressive video, high-performance computing, very large data sets at hundreds of gigabytes, and high-speed networking that allows the user to be enveloped in the data presentation with a capability for real-time manipulation. The Defense Research and Engineering Network (DREN) is a high-speed continental United States network that connects the four Major Shared Resource Centers (MSRCs) and 19 Distributed Centers (DCs) of DDR&E's High Performance Computing Modernization Program (HPCMP) as well as a number of user organizations that use the HPCMP resources.

As one of the 19 Distributed Centers in the HPCMP, ITD's Center for Computational Science supports a range of shared resources including massively parallel computer systems and high-performance networks. Current systems include an SGI Origin3800 with 128 processors and 128 Gbytes of memory. A next generation Sun HPC is scheduled for delivery in the first quarter FY 02, followed by a Cray/Tera multi-threaded architecture machine in the second quarter FY 02. The CCS also has more than 12.5 Tbytes of on-line shared rotating disk as well as robotic storage systems for fileserving and archiving that hold 300 Tbytes of multimedia data but are scalable to over a Petabyte. The Center manages the NRL local area network, NICEnet, which has transitioned from the older FDDI and shared Ethernet local area networks to a fully switched environment based on ATM backbones, and both high-speed

Ethernet and ATM to the users' desktops. The evolutionary goal is to provide digital transparency of resources with security across the information infrastructure—from globally available archives, to the computational engines, to the networks that bring it all together at 10 Gbps directly to the desktops of the most demanding users. NICEnet provides external connections to other networks and to the Internet.

The division facilities also include an Information Security Engineering Laboratory, a Robotics Laboratory, a high-data-rate multimedia satellite transmission facility, and an experimental facility with special displays, eye and gesture trackers, and audio and speech I/O devices for research in human/computer interaction. Laboratories for the development and testing of communication and network protocols both for Internet Protocols (IP) and ATM research are also included. These network testbeds are routinely interfaced to the DOD wide-area research networks for collaboration with other government laboratories. A wireless networking testbed is being used to develop Mobile Ad Hoc Networking (MANET) standards that can meet a wide range of military and commercial needs.

The Virtual Reality (VR) Laboratory provides the facilities and expertise to allow NRL scientists to use virtual reality in a variety of scientific investigations. Research areas include shipboard firefighting; simulation-based design; command and control; and scientific visualization. A number of high-speed graphics workstations, including Onyx Reality Engine 2 and Infinite Reality computers, and a variety of VR peripherals comprise the VR Lab computer equipment inventory.

Current VR technologies available include desktop VR systems, head-mounted displays (HMDs), the Responsive Workbench, and the surround-screen Immersive Room. The Responsive Workbench is an interactive 3-D tabletop environment that displays computer-generated, stereographic images on the workbench surface for use in battlespace situation awareness, simulation-based design, and other applications. The surround-screen Immersive Room is a multiuser, high-resolution 3-D visual and audio environment that projects computer-generated images onto three walls and the floor to create an immersive, large-scale, shared virtual environment. It uses an SGI Onyx RE2 so scientists can interact and control their supercomputing calculations in real time.

The NEWAVE facility has been developed as a multiscreen distributed simulation laboratory and viewport. Powered by SGI and Pentium workstations and linked to the NRL parallel computing facilities with ATM/SONET networking, the facility is capable of handling high-performance computing, graphics, and distributed simulation.

NRL has owned and operated a Ship Motion Simulator (SMS) since 1943. This facility is currently located at the NRL Chesapeake Bay Detachment. Originally developed to provide gunnery practice for sailors, the SMS has been used more recently to test radar and satellite receiving systems. A roll motion of up to 28 degrees (14 degrees to port and 14 degrees to starboard) can be applied to the roll axis. The pitch axis has a fixed motion of 10 degrees (5 degrees to stern and 5 degrees to bow). Periods along both the pitch and roll axes are variable—from a slow 20-s to a brisk 8-s per cycle.

A 7-ft × 12-ft operations van (Connex box) was recently mounted on the SMS, following suitable structural modifications to the platform. The van can accommodate 4 to 5 experimenters and subjects. A

NRL's Ship Motion Simulator currently located at the Chesapeake Bay Detachment, near Chesapeake Beach, Maryland.

work area provides adequate space for computer monitors and support hardware. Climate control is maintained by a heat pump. The integrated van/SMS system is designed to be a permanent NRL facility for evaluating the impact of shipboard motion upon human performance. This research was sponsored by Aviation Medicine, Code 341, and Virtual Environment Technologies, Code 342, at the Office of Naval Research. The point of contact is Dr. Roger Hillson, Code 5580, NRL.

Optical Sciences

The Optical Sciences Division has a broad program of basic and applied research in optics and electro-optics. Areas of concentration include fiber optics, integrated optical devices, signal processing, optical information processing, fiber-optic and infrared (IR) sensors, laser development, surveillance, and reconnaissance.

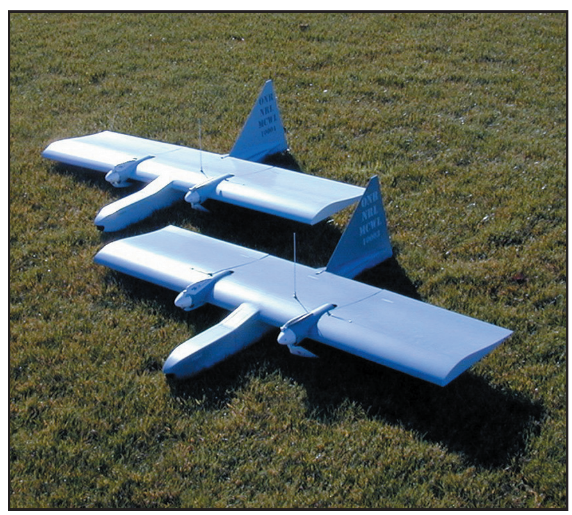
The division occupies some of the most modern optical facilities in the country. This includes an Ultralow-loss, Fiber-Optic Waveguide Facility using high-temperature infrared glass technology. There is also a Focal-Plane Evaluation Facility to measure the optical and electrical characteristics of infrared focal-plane arrays being developed for advanced Navy sensors. The IR Missile-Seeker Evaluation Facility performs open-loop measurements of the susceptibilities of IR tracking sensors to optical countermeasures. The Large-Optic, High-Precision Tracker system is used for atmospheric transmission and target signature measurements. The Infrared Test Chamber is an ultradry test chamber used to measure the IR signatures of new surface treatments, scale models, and components used for observable control on ships, aircraft, and missiles. An UHV multichamber deposition apparatus for fabrication of electro-optical devices is interfaced to a surface analysis chamber equipped with UPS, XPS, AFM, and STM. Other scanning probe facilities are equipped with Atomic Force and Magnetic Force Microscopes.

There are several fiber-optic sensor facilities with fiber splicers, an acoustic test cell, a three-axis magnetic sensor test cell, equipment for evaluating optical fiber coatings, and various computers for concept analysis. The Digital Processing Facility is used to collect, process, analyze, and manipulate infrared data and imagery from several sources. The Emittance Measurements Facility performs measurements of directional hemispherical reflectance. An extensive set of laboratories exists to develop and test new laser and nonlinear frequency conversion concepts and to evaluate nondestructive test and evaluation techniques.

The newest facilities are a scanning probe facility equipped with both an atomic force microscope and a magnetic force microscope and an ultra-high vacuum, surface analysis chamber with both X-ray and ultraviolet photoemission spectroscopy for determination of energy levels in metals, semiconductors, and organic materials.

Electronic Warfare

The scope of the Tactical Electronic Warfare (TEW) Division's program for electronic warfare (EW) research and development covers the entire electromagnetic spectrum. The program includes basic technology research and advanced developments and their applicability to producing EW products. The range of ongoing activities includes components, techniques, and subsystems development as well as system conceptualization, design, and effectiveness evaluation. The focus of the research activities extends across the entire breadth of the battlespace. These activities emphasize providing the methods and means to counter enemy hostile actions—from the beginning, when enemy forces are being mobilized for an attack, through to the final stages of the engagement. In conducting this program, the TEW Division has an extensive array of special research and development laboratories, anechoic chambers, and modern computer systems for modeling and simulation work. Dedicated field sites and an NP-3D EW flying laboratory allow for the conduct of field experiments and operational trials. This assembly of scientists, engi-



The U.S. Marine Corps Dragon Eye is an affordable, expendable airborne sensor platform for small unit reconnaissance and threat detection. The full-up system consists of a man-portable, 4.5-pound hand-launched air vehicle (shown) and a Ground Control Station to provide vehicle control and data retrieval.

neers, and specialized facilities also supports the innovative use of all Fleet defensive and offensive EW resources now available to operational forces through the Naval Fleet/Force Technology Innovation Office.

Laboratory for Structure of Matter

This laboratory investigates the atomic arrangements in materials to improve them or facilitate the development of new substances. Various diffraction methodologies are used to make these investigations. Subjects of interest include the structural and functional aspects of energy conversion, ion transport, device materials, and physiologically active substances such as drugs, antibiotics, and antiviral agents. Theoretical chemistry calculations are used to complement the structural research. A real-time graphics system aids in modeling and molecular dynamics studies. The facilities include three x-ray diffraction units, two being state-of-the-art facilities, and an atomic force microscope.

Chemistry

NRL has been a major center for chemical research in support of naval operational requirements since the late 1920s. The Chemistry Division continues this tradition with a broad spectrum of basic and applied research programs focusing on controlled energy release (fuels, fire, combustion, countermeasure decoys, explosives), surface chemistry (corrosion, adhesion, tribology, adsorbents, film growth/etch), advanced materials (high-strength/low-weight structures, drag reduction, damping, polymers, thin films), and advanced detection techniques (environment, chemical/biological, surveillance). Facilities for research include:

Chemical analysis facilities, including a wide range of modern photon/electronic, magnetic- and ion-based spectroscopic/microscope techniques for bulk and surface analysis;

Synchrotron Radiation Facility, with intense, monochromatic X-ray photon beams tunable from 10 eV to 12 KeV available from two beam lines developed by NRL at the National Synchrotron Light Source at the Brookhaven National Laboratory. Environmental target chambers span a pressure range from 10^{-12} to 10^{5} atm and temperatures from 10 to 1500 K;

Nanometer measurement facility, which includes fabrication and characterization capability based on scanning tunneling microscopy/spectroscopy, atomic force microscopy, and related techniques;

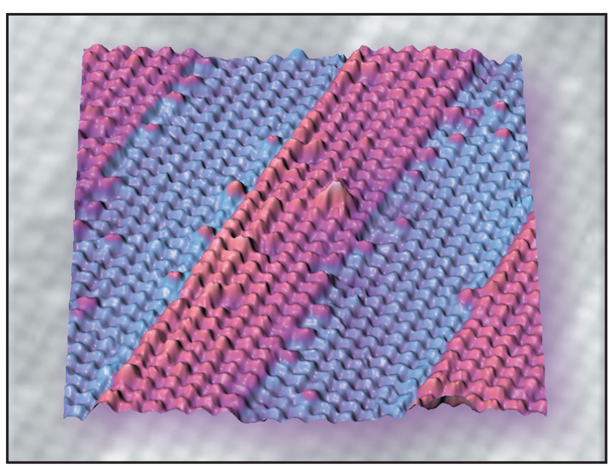
Materials synthesis/property measurement facility, with special emphasis on polymers and surface/film processing;

Fire research facilities, ranging from laboratory combustion chemistry to a 10^4 ft^3 fire-research chamber (Fire I) and the 475-ft ex-USS *Shadwell* (LSD-15) advanced fire research ship; and

Marine Corrosion Test Facility, located on Fleming Key at Key West, Florida, offers an ocean-air environment and clean, unpolluted, flowing seawater for studies of environmental effects on materials. Equipment is available for experiments involving weathering, general corrosion, fouling, and electrochemical phenomena as well as coatings, cathodic protection devices, and other means to combat environmental degradation.

Materials Science and Technology

NRL has capabilities for X-ray and electron-diffraction analyses and for electron and Auger spectroscopy. Scanning, transmission, and combined scanning-transmission electron microscopes are used to study surface and/or internal microstructures. The



Color-enhanced scanning tunneling microscopy image of a cross-section showing the atomic-scale structure at the interfaces between GaSb and InAs superlattice layers. This work, incorporating sample preparation by scientists in the Electronics Sciences and Technology Division, STM measurement and interpretation by Chemistry Division staff, and modeling by theorists in the Materials Science and Technology Division, illustrates the multidisciplinary character of NRL research.

division has a secondary ion mass spectrometer for surface analysis that significantly extends the diagnostic capability of the technique. A high-resolution, reverse-geometry mass spectrometer is used to probe reactions between ions and molecules. The Laboratory has a fully equipped fatigue and fracture laboratory and hot isostatic press facilities. The Laboratory's cryogenic facilities include dilution refrigerators and superconducting magnetic sensors for measuring ultrasmall magnetic fields. Also available are two molecular beam epitaxy devices for growing thin films. In addition, division facilities include:

High-Power Microwave (HPM) Facility: The large anechoic chamber (4.9 m × 4.9 m × 9.8 m) can be used at frequencies ranging from 0.5 to 94 GHz. Effects, susceptibility, and survivability of systems are the major research areas of interest.

Trace Element Accelerator Mass Spectrometry (TEAMS) – 3 MV Tandem Pelletron Accelerator Facility: Used for standard materials analysis such as Rutherford backscattering, for MeV-energy ion implantation, and for accelerator mass spectrometry (AMS). AMS measures trace elements in parallel with 3-D imaging at 10-µm lateral resolution (0.01 µm in depth) to 10-ppt sensitivity, and isotopes for sample dating and forensics.

Laser Facilities: Pulses of up to several joules are available from one system, while time resolutions down to 30 femtoseconds are produced by another. Synchronized Q-switched oscillators are configured for pump-probe experiments.

Thin-Film Preparation Facilities: The division has several major capabilities for preparation of thin films of advanced materials, such as high-temperature superconductors and active dielectrics. These include ion-assisted evaporation (which produces dense, adherent films), various dc plasma sources (which can etch as well as deposit films), and pulsed laser deposition (for production of chemically complex films).

Ion Implantation Facility: The facility consists of a 200-keV ion implanter with specialized ultrahigh vacuum chambers and associated in situ specimen analysis instrumentation.

Laboratory for Computational Physics and Fluid Dynamics

The Laboratory for Computational Physics and Fluid Dynamics (LCP & FD) is in round-the-clock production for computational studies in the fields of compressible and incompressible fluid dynamics, reactive flows, fluid-structure interaction (including submarine, ship, and aerospace applications), plasma physics, atmospheric and solar magnetoplasma dynamics, application of parallel processing to large-scale problems such as unstructured grid generation for complex flows, and other disciplines of continuum and quantum computational physics. The facility is used to develop and maintain state-of-the-art analytical and computational capabilities in fluid dynamics and related fields of physics, to establish in-house expertise in parallel processing and on-line graphical rendering for large-scale scientific computing, to perform analyses and computational experiments on specific relevant problems, and to transfer this technology to new and ongoing projects through cooperative programs.

LCP maintains a very powerful collection of computer systems applied to a broad collection of work. There are currently a total of 150 parallel SGI processors, 80 parallel HP processors, 72 clustered Alpha processors, and several other support systems. In addition, there are over 50 Macintoshes in the group, most of which are capable of large calculations both independently and in parallel ad hoc clusters.

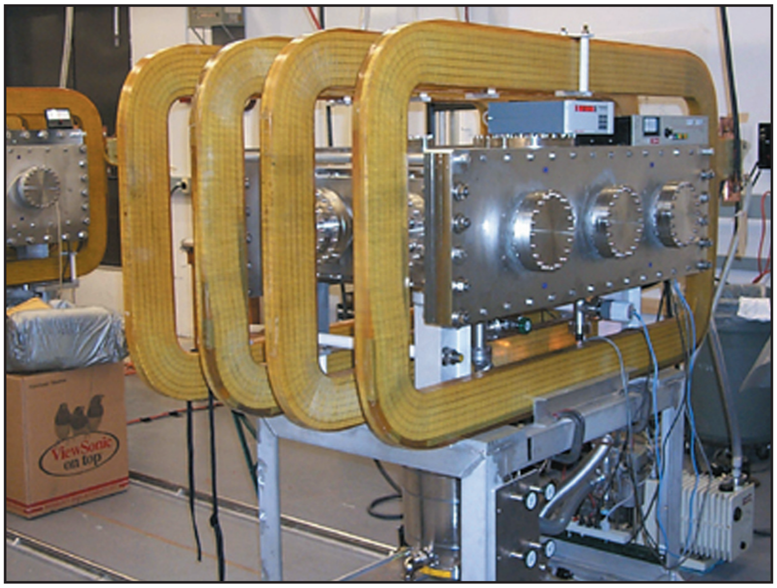
The individual systems are compised of a 64 R12K processor SGI Origin 2000, a 32 R10K processor Origin 2000, a 28 R12K processor Origin 3400, an 18 R10K processor Power Challenge, and an 8 R12K processor Origin 2400. The HP Exemplar systems are a 64 processor X-Class SPP system and a 16 processor S-Class SPP system. The Alpha cluster is a collection of API Alpha 21264 processor Linux systems well coupled with a Myrinet high-speed switched interconnect.

Each system has on the order of 200 Gbytes of disk space for storage during a simulation, and at least 256 Mbytes of memory per processor. All unclassified systems share a common disk space for home directories as well almost 250 Gbytes of AFS space that can be used from any AFS-capable system throughout the allowed Internet.

The AFS capability also allows access to other storage systems including NRL's multiresident AFS (MRAFS) system, which automatically handles archival to a multiterabyte tape archival system.

Plasma Physics

The Plasma Physics Division is the major center for in-house Navy and DOD plasma physics research. The division conducts a broad experimental and theoretical program in basic and applied research in plasma physics, which includes laboratory and space plasmas, pulsed-power sources, plasma discharges, intense electron and ion beams and photon sources, atomic physics, laser physics, advanced spectral diagnostics, plasma processing, nonlinear dynamics and



Source chamber of the Large Area Plasma Processing System (LAPPS) processing reactor. The coils generate 100-200 Gauss magnetic fields inside the stainless steel high vacuum chamber. A low current electron beam is produced in the chamber that generates large area plasma sheets. These sheets are then used for processing materials such as etching silicone or coating plastics.

chaos, and numerical simulations. The facilities include an extremely high-power laser—Pharos III—for the laboratory simulation of space plasmas and nuclear weapons effects studies and a short pulse, high-intensity Table-Top Terawatt (T^3) laser to study intense laser-plasma, laser-electron beam, and laser-matter interactions. The division also has an 11 m^3 space chamber capable of reproducing the near-Earth space plasma environment and a Large Area Plasma Processing System (LAPPS) facility to study material modification such as surface polymerization or ion implantation. The division has developed a variety of pulsed-power sources to generate intense electron and ion beams, powerful discharges, and various types of radiation. The largest of these pulsers—GAMBLE II—is used to study the production of megampere electron and ion beams and to produce very hot, high-density plasmas. Other generators are used to produce particle beams that are injected into magnetic fields and/or cavities to generate intense microwave pulses. A large array of high-frequency microwave sources (2.45, 35, and 83 GHz) are available to conduct research on microwave processing of advanced ceramic materials. In particular, the division added a 15-kW, continuous wave, 83 GHz gyrotron to its facility for research on high-frequency microwave processing of materials. The Russian-made gyrotron produces a focused, high-intensity millimeter-wave beam (10^3-10^5 W/cm^2) that has unique capabilities for rapid, selective heating of a wide range of nonmetallic materials. The new gyrotron-based system will be used to investigate the application of such beams to important areas of material processing, including coating of materials, soldering and brazing, and treatment of ceramics, semiconductors, and polymers.

A major 3 kJ KrF laser facility (Nike) opened in June 1995. This facility is made up of 56 laser beams and is single pulsed (4 nanosecond pulse). This facility provides intense radiation for studying inertial confinement fusion (ICF) target heating at short wavelengths (0.25 microns) and high-pressure physics.

Electronics Science and Technology

In addition to specific equipment and facilities to support individual science and technology programs, NRL operates the Nanoelectronics Processing Facility (NPF), the Compound Semiconductor Processing Facility (CSPF), the MOCVD Laboratory, the EPICENTER, the Vacuum Electronics Fabrication Facility (VEFF), the Ultrafast Laser Facility (ULF), and the Space Solar Cell Characterization Facility (SSCCF). The NPF's mission is to provide service to both NRL and external organizations requiring micro- and nanofabrication processing support. Lithography is a particular strength of the NPF, with definition of feature sizes down to 150 angstroms possible with an e-beam nanowriter. The NPF can supply items ranging from individual discrete structures and de-

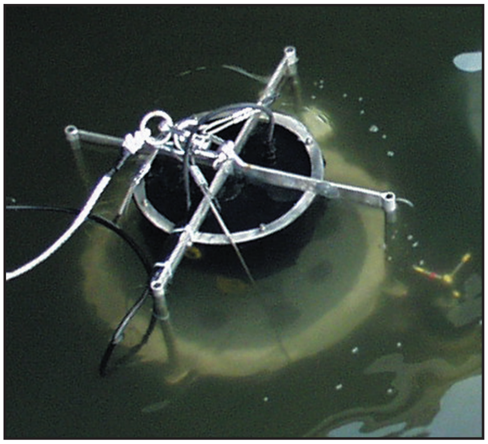
Electron beam nanowriter in use defining geometries as small as 50 Å (approximately 10 atomic layer spacings).

vices to circuits with very-large-scale integration complexity. The CSPF is dedicated to processing III-V semiconductor devices and circuits in addition to serving the hands-on fabrication needs of individual NRL scientists. The CSPF uses a single-pass air-ventilation system to minimize human risk from potentially hazardous III-V semiconductor processes and associated chemicals, thereby further meeting existing safety standards. The MOCVD Laboratory uses organometallic vapor phase epitaxy to synthesize a wide range of thin films such as InSb, InGaP, InP, and GaN. The EPICENTER (a joint activity of the Electronics Science and Technology, Materials Science and Technology, Optical Science, and Chemistry Divisions) is dedicated to the production of multilayer microstructures using in situ surface analytical techniques in one of several ultrahigh vacuum, molecular-beam-epitaxy growth and processing chambers—one for growth of conventional III-V semiconductors, one for vacuum processing, one for growth of III-V semiconductor ferromagnetic materials, one for growth of 6.1 angstrom III-V semiconductors, and another for growth of magnetic materials and II-VI semiconductors. The Ultrafast Laser Laboratory is optimized for the characterization of photophysical and photochemical processes in materials on a timescale of tens of femtoseconds and also includes a synchronously pumped dye laser system for simulating the effects of charge deposited in semiconductors characteristic of space radiation. The SSCCF studies the effect of particle irradiation on new and emerging solar cell technologies for space applications. The VEFF provides electrical and mechanical design, fabrication, assembly, modification, and repair, as well as processing services for vacuum electronic devices.

Bio/Molecular Science and Engineering

The Center for Bio/Molecular Science and Engineering conducts research and development using biotechnological approaches to solve problems for the Navy, DOD, and the nation at large. Problems currently being addressed include advanced material development (for electronic, biomedical, and structural applications), environmental quality (including pollution cleanup and control), and biological warfare defense. The approach to these problems involves long-term research focused on the study of complex materials systems, coupled with integrated exploratory and advanced development programs. The staff of the Center is an interdisciplinary team that performs basic and applied research and development in areas that require expertise in bio- and surface chemistry, biophysics, genetic engineering, cell biology, advanced organic synthesis, solid-state and theoretical physics, and electronics and materials engineering. In addition, the Center has many collaborations throughout the Laboratory, at universities, and in industry to ensure that a broad base of the required expertise and critical evaluations are part of the research and development programs. Highlights of the program include the manipulation of biologically derived structures on the nanometer scale, the development of ferroelectric liquid crystal systems with microsecond response times, discovery of an advanced resist system for high-speed, high-density integrated circuits, the patterning of neuronal cells to form neural networks, and the development of biosensors for environmental monitoring.

The Center occupies laboratories and offices in Building 30. These modern facilities, designed to be



Ocean Floor Bio-Fuel Cell prototype being developed to harvest energy from the ocean floor to power autonomous marine deployed instrumentation. Two electrodes in the device are positioned across the seawater-sediment interface to draw power from naturally occurring microbes.

used well into this century, include general laboratories for research in chemistry, biochemistry, molecular biology, and physics. Specialized areas include a 600-ft^2 Class 1000 clean room; an advanced Electron Microscope facility; and a Scanning Probe Microscope laboratory. Instrument rooms provide access to a variety of spectrophotometers (IR, GC-MS, NMR, and UV-Vis) and other equipment used in biochemical or physical analyses of biomaterials. Additional laboratories accommodate an X-ray diffraction instrument, a liquid crystal fabrication facility, and equipment for advanced electronics and biosensor programs.

Acoustics

The Acoustics Division has three integrated structural acoustic facilities—two pools including one with a sandy bottom and a large in-air, semi-anechoic laboratory—that support research in submarine target characteristics for antisubmarine warfare, submarine acoustic design and quieting, sensors for hull mounted sonars, mine detection and identification, torpedo quieting, and noise control in the interior of air and submarine structures. Scaled submarine targets, real mines, sensors mounted on hull simulators, underwater buried objects, actual torpedoes, small aircraft fuselages, and satellite payload launch fairings can all be examined with advanced nearfield holographic and scanning 3-D laser vibrometer systems to measure and visualize the sound fields near a structure, the vibrations of the structure itself, the resulting farfield and interior sound fields, and the physics of the sound-structure-fluid interactions.

The division operates state-of-the-art laboratories equipped to study the structural dynamics and performance of high-Q oscillators and other micro-mechanical systems. A number of laser Doppler vibrometers permit the spatial mapping of the complex vibratory motion of the micro-oscillators. Nanostructures are probed with a super-resolution near-field scanning optical microscope, or NSOM, allowing the monitoring of modes with a spatial resolution of 100 nm. These unique databases can be used to identify and analyze the modes of vibration and the various loss mechanisms with a view toward pushing the Q to still higher levels and for designing optimum oscillator coupling for micro and nano-oscillator array applications. In addition, the viscoelastic properties of thin films can be studied by depositing them on portions of the oscillator. The laboratory includes the ability to measure many of these mechanical and electrical properties down to 370 mK.

The division operates several sound sources for the generation and reception of sound in at-sea experiments. Sound sources include three XF-4 units, one ITC 2077 source that can be operated while being towed by a ship, and two battery-operated organ-pipe sources that can project single tones from offboard moorings. In addition, the division has several battery-operated rubidium-clock controlled, programmable sound source moorings that can transmit sounds having arbitrary waveforms.

The division has a number of acoustic receiving arrays for at-sea experiments. Receive systems include a moored 32-channel array that RF telemeters data to a recording site at a rate up to 50 kHz/channel, a 16-channel midfrequency array, and a 128-channel autonomously recording receiving system with 2.2 terabyte capacity. These systems acquire data with rubidium-clock sampling accuracy. The division also has unique, self-recording digital acquisition buoy systems (DABS) that are used to obtain multichannel (up to 128) acoustic data in the 10-Hz to 5-kHz regime. These systems provide up to 250 Gbytes of data on a single 15-inch reel of 1-inch tape.

The division has a 32-channel (expandable to a 64-channel) broadband source-receiver array with time reversal mirror functionality. Projects involving scanning focused acoustic fields and phase conjugation for multistatic sonar will use the new array to test and study time reversal methods. The transducers for the array are 6-inch spheres that operate over a frequency band of 500 to 3500 Hz.

The Acoustics Division has a satellite-linked buoy system with underwater receive arrays designed to collect acoustic and oceanic data, unattended, for periods of up to one month. The system currently can handle 64 channels of acoustic data (distributed on one or two arrays), and can implement onboard signal processing prior to data transmission. Two-way satellite communication is supported, providing a high-speed data link (up to 1.5 Mbps) for data transfer from the buoy to shore, and a low-speed command and control link to remotely control buoy functions. The system also contains high-speed (up to Mbps) line-of-sight communications using a GPS-linked directional antenna.

The division conducts underwater acoustic communications research using digital, acoustic modems capable of receiving and processing signal from 8 channels at various carrier frequencies and with various bit rates. An Acoustic Communication Laboratory provides environment simulation, pre-experiment testing and preparation, and post-experiment data analysis.

A narrowbeam 200 and 350 kHz backscattering system is used to study internal wave and larger scale turbulent processes. The system is used to estimate the magnitude of the randomization of the sound speed field by a variety of fluid processes. The system consists of a deck-mounted towing assembly, power and signal amplifiers, as well as a real-time display and digital data acquisition system. In addition, a 25-kw narrowbeam radar is used to take surface manifestation of fluid processes including internal waves and fronts in conjunction with the acoustic system.

The division operates high-frequency (up to 600 kHz) acoustic measurement systems to obtain scattering, target strength, and propagation data using bottom-moored instrumentation towers and a high-speed, remotely operated vehicle. These data are used to simulate the performance of weapons and mine countermeasure sonars.

The Tactical Oceanography Simulation Laboratory (TOSL) is a modeling and simulation architecture consisting of a set of tools for processing climatology and real-time environmental data and applying energy propagation models to those data. TOSL features a high-performance computational capability to provide calculations in support of training, war games, operations rehearsal, and other distributed simulation functions. TOSL is coupled via Ethernet and SIPRNET with the Tactical Oceanography Wide Area Network (TOWAN) repository of environmental data, which allows full participation in a distributed simulation environment.

Remote Sensing

The Remote Sensing Division conducts a program of basic research, science, and applications to develop new concepts for sensors and imaging systems for objects and targets on Earth, in the near-Earth environment, and in deep space. The research, both theoretical and experimental, leads to discovery and understanding of the basic physical principles and mechanisms that give rise to background environmental emissions and targets of interest and to absorption and emission mechanisms of the intervening medium. Accomplishing this research requires the development of sensor systems' technology. The developmental effort includes active and passive sensor systems used for study and analysis of the physical characteristics of phenomena that evolve from naturally occurring background radiation, such as that caused by the Earth's atmosphere and oceans and man-made or induced phenomena, such as ship/submarine hydrodynamic effects. The research includes theory, laboratory, and field experiments leading to ground-based, airborne, or space systems for use in remote sensing, astrometry, astrophysics, surveillance, nonacoustic ASW, meteorological/oceanographic support systems for the operational Navy, and the environmental/global climate change initiatives. Special emphasis is given to developing space-based platforms and exploiting existing space systems.

The Remote Sensing Division conducts airborne hyperspectral data collections for characterization of the environment. Hyperspectral data are series of pictures, taken simultaneously, of a scene at many different wavelengths (colors). The sensors are built and calibrated in-house, although they rely heavily on commercial off-the-shelf elements. The most recent sensor was specifically designed for use over ocean areas. It covers the 400 to 1000 nanometer wavelength range with 128 different wavelengths (channels). The sensor consists of a standard video camera lens, a grating spectrograph, and a 1024 × 1024 pixel charge-coupled device (CCD). The spectrograph and CCD are specially designed to achieve high sensitivity in the blue end of the spectrum to optimize water-penetrating measurements. This makes possible measurements such as the determination of the ocean bottom type (coral, sea grass, sand, rock, etc.) to water depths of as much as 20 meters (in clear water), and the identification of material in the water column (phytoplankton, sediments, colored dissolved organic matter, etc.). The sensor is very compact and can be flown at heights of 8000 to 10,000 feet, simply "looking" out of a hole in the bottom of the airplane. At ground speeds of 90 knots, the data can still be collected digitally and stored on computer. They are then processed in a ground system operating on a standard personal computer.

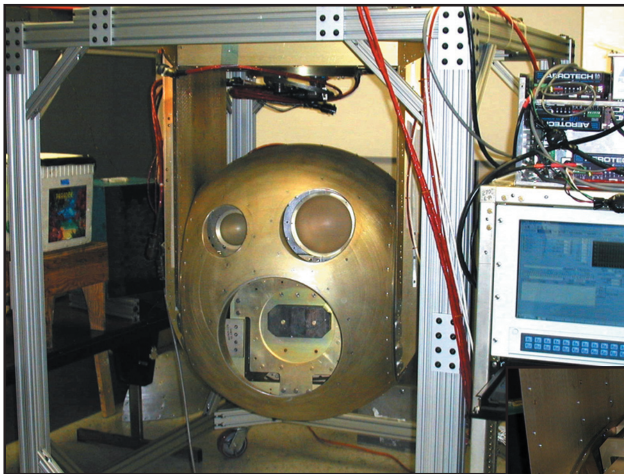
Proper interpretation of the hyperspectral data requires calibration of the sensor. This means both radiometric and spectral calibration. The latter plays a critical role in the successful correction of the data for atmospheric effects. The Remote Sensing Division operates an Optical Calibration Facility to perform these calibrations. NIST radiometric standards are transferred to a large integrating sphere. The integrating sphere has 10 precisely controlled quartz-halogen lamps to enable linearity measurements. A set of gas emission standards provides wavelength calibration. As a result, the complete process of data collection through data analysis can be handled in-house.

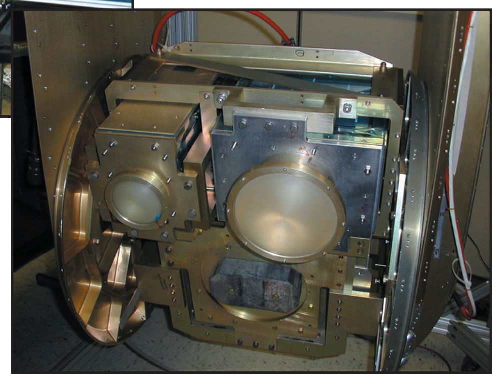
In order to validate the results of airborne hyperspectral sensing and to support the interpretation of the physical processes they reveal, the Remote Sensing Division has developed a Profiling Optics Package. This system measures the inherent optical properties of water (absorption, attenuation, and scattering) in the 400 to 700-nanometer range, and collects water samples for various laboratory measurements. The package was built around a Seabird Rosette frame and includes a WETLabs Histar meter to measure water absorption and attenuation at 103 wavelengths; and unfiltered WETLabs ac9 meter to measure water absorption and attenuation at 9 wavelengths; a filtered WETLabs ac9 to measure colored dissolved organic matter (CDOM) absorption and attenuation at 9 wavelengths; a HOBILabs Hydroscat to measure backscattering of water in 6 wavelengths; a WETLabs WetStar fluorometer to measure stimulated fluorescence of chlorophyll; a Seabird CTD to measure conductivity (salinity), temperature, and depth; and eight sample bottles to collect up to 20 liters of water. Data from each sensor are collected and archived inside a WETLabs Super MODAPS instrument. They are then transmitted to the surface via an armored sea cable, where they are stored on a computer disk. The package has a maximum depth rating of 300 meters, although it is usually operated in coastal waters of less than 50 meters.

The Navy Prototype Optical Interferometer (NPOI), a major facility of the Remote Sensing Division, is actually two collocated instruments for making high-angular-resolution optical measurements of stars. Light from widely separated individual siderostats is combined simultaneously to synthesize the angular resolution of a telescope tens to hundreds of meters in diameter. Four siderostats are placed in an array with extremely accurate metrology to enable very-high-precision measurements of stellar positions (wide-angle astrometry). These measurements are used by the U.S. Naval Observatory to refine the celestial reference frame, determine Earth rotation parameters, and thus satisfy Navy requirements for precise time and navigation data. They also provide determinations of basic astrophysical parameters, such as stellar masses and diameters. Additional relocatable siderostats can be placed out to distances of 250 m from the array center and used to construct very-high-resolution images of stars. These images provide fundamental astrophysical information on stellar structure and activity. When complete, the NPOI will be the most advanced high-resolution imaging optical interferometer in the world.

Profiling Optics and Water Return (POWR) system. White Seabird carousel frame protects underwater optical instruments (black cylinders) and water sample bottles (gray cylinders).

To validate numerical and theoretical efforts ongoing within the Remote Sensing Division, extensive hierarchical-coupled experiments are carried out in the Free-Surface Hydrodynamics Laboratory. This laboratory is used to study free-surface turbulence interactions, wave-generation phenomena, jet-flow phenomena, vorticity dynamics, and free-surface/surfactant interactions. Emphasis is placed on those processes that determine the fluxes of heat, mass, and momentum across the air-sea interface. State-of-the-art diagnostic tools are available, such as Langmuir film balance to measure the properties of surface films, hot-wire and laser-Doppler anemometry, and the new quantitative flow techniques of laser speckle, particle tracking, and particle image velocimetry. The laboratory is also equipped with an IR camera with a 20×10^{-3} K resolution. These experimental diagnostic techniques use high-powered lasers, high-tolerance optical lenses, and extensive ultra-high-resolution video-imaging hardware and PC-based computerized systems. Further computational assets consist of powerful graphical computer work stations, the NRL Connection Machine, and other off-site Cray supercomputer systems.





Above—APMIR in its laboratory test fixture with radomes removed. The spherical assembly fits in the P3 bomb bay and rotates in both azimuth and elevation.
Right—The sphere body is removed to show the radiometers. The lenses are part of the 18, 22, and 37 GHz antennas.

The Airborne Polarimetric Microwave Imaging Radiometer (APMIR) is a state-of-the-art multichannel microwave radiometer system being designed and built by the Remote Sensing Division. APMIR is being developed in response to the emerging need for extensive airborne calibration and validation of spaceborne remote sensing assets: the SSMIS, WindSat, and CMIS spaceborne microwave imaging systems. APMIR will cover five frequency bands: 5-7, 10.7, 18.7/19.35, 22.23/23.8, and 37.0 GHz. Frequency agility allows for frequency matching to each of the spaceborne systems of interest. The 10.7, 18.7/19.35, and 37.0 GHz channels are fully polarimetric, and will thus measure the ocean surface wind speed and direction. The 5 to 7 GHz channel simultaneously observes several frequencies, providing sensitivity to sea surface temperature; the means to separate rain effects from surface effects; and protection from radio frequency interference (RFI). The 22.23/23.8 GHz channels respond to the atmospheric water vapor in the column below the aircraft, while the 18.7/19.35 and 37.0 GHz channels are sensitive to both ocean surface and cloud parameters. The APMIR system will be mounted in the bomb bay of the NRL P-3 aircraft and flown at altitudes ranging from 500 to 25,000 feet over the ocean.

Oceanography

The Oceanography Division is the major center for in-house Navy research and development in oceanography. It is known nationally and internationally for its unique combination of theoretical, numerical, experimental, and remote sensing approaches to oceanographic problems. The division numerically models the ocean and coastal areas of the world. This modeling is conducted on the Navy's and DOD's most powerful vector and parallel-processing machines. To study the results of this intense modeling effort, the division operates a number of highly sophisticated graphic systems to visualize ocean and coastal dynamic processes. The seagoing experimental programs of the division range worldwide. Unique measurement systems include a wave measurement system to acquire in situ spatial properties of water waves; a salinity mapper that acquires images of spatial and temporal sea surface salinity variabilities in littoral regions; an integrated absorption cavity, optical profiler system, and towed optical hyperspectral array for studying ocean optical characteristics; and self-contained bottom-mounted upward-looking acoustic Doppler current profilers for measuring ocean variability. In the laboratory, the division operates an environmental scanning electron microscope for detailed studies of biocorrosion in naval materials. The division's remote sensing capabilities include the ability to analyze and process multi/hyperspectral, IR, SAR, and other satellite data sources. The division is a national leader in the development and analysis of Sea WiFS data for oceanographic processes and naval applications in littoral areas.

Marine Geosciences

The Marine Geosciences Division is the major Navy in-house center for research and development in marine geology, geophysics, geodesy, geoacoustics, geotechnology, and geospatial information and systems. The division has unique suites of instrumentation and facilities to support laboratory and field experimental programs.

The instrumentation used in the field experiments is deployable from ships, remotely operated and unmanned vehicles, and airborne platforms and by divers. Seafloor and subseafloor measurements use the Deep-Towed Acoustic Geophysical System (DTAGS—250 to 650 Hz); high-resolution sidescan sonars (100 and 500 kHz); the Acoustic Seafloor Characterization System (ASCS-15, 30, and 50 kHz); ocean bottom seismometers and magnetometer; the In Situ Sediment Acoustic Measurement System (ISSAMS); underwater stereo photography; and nearshore video imaging systems. ISSAMS has specialized probes that measure acoustic compressional and shearwave velocities and attenuation, pore water pressure, and electrical conductivity in surficial marine sediments. The Remote Mine Hunting System, Oceanographic (RMSO), an unmanned, diesel-powered, radio-controlled, 8-m semisubmersible, is used to develop improved hydrographic survey techniques, sensor systems, and navigation capabilities.

Laboratory facilities include sediment physical, geotechnical, and geoacoustic properties and sediment core laboratories. The Electron Microscopy Facility is the focal point for research in microscale biological, chemical, and geological processes. The key instrumentation includes a 300 kVa transmission electron microscope with environmental cell. The environmental cell allows hydrated and gaseous experiments. The Moving Map Composer Facility is used to design and write mission-specific map coverages for F/A-18 and AV-8B tactical aircraft onto militarized optical disks. The National Imagery and Mapping Agency also uses this state-of-the-art computer facility to update the compressed aeronautical chart library on CD for distribution. The Geospatial Information Data Base (GIDB) capability provides Internet access to the Digital Nautical Chart data, mapping data, imagery, and other data types such as video and pictures. This development tool can be used for planning, training, and operations. The division also operates the NRL Magnetic Observatory at Stennis Space Center, Mississippi. This magnetically clean area consists of an array of magnetometers that measure Earth's ambient magnetic field. The observatory is part of a worldwide observing system.

Marine Meteorology

The Marine Meteorology Division is located in Monterey, California. NRL-Monterey (NRL-MRY) is the only Navy facility with a mission to serve the Navy's needs for basic research in meteorology sciences and its need for the development of meteorological analysis and prediction systems to support global and tactical operations. The division is dedicated to advancing fundamental scientific understanding of the atmosphere, to applying scientific discoveries in the development of innovative objective weather prediction systems, and to developing ways to provide atmospheric data input to the tactical decision maker.

NRL-MRY is collocated with Fleet Numerical Meteorology and Oceanography Center (FNMOC), the Navy's operational center of expertise in numerical weather prediction. This provides NRL-MRY efficient access to a variety of classified and unclassified computer resources, databases, and numerical prediction systems. Large supercomputer mainframes and databases at FNMOC are used along with DOD High Performance Computing Modernization Program resources and local NRL-MRY resources to develop and transition operational analysis and prediction systems, and to provide on-site and remote access to the model output data for continued research purposes. In addition, interfaces to the Defense Research and Engineering Network have also been established.

Locally, to support research and development needs, NRL-MRY has established the Bergen Data Center. This Center includes a 24TB capacity data center with a hierarchical storage management capability to provide archival and easy retrieval of research data sets. The John B. Hovermale Visualization Laboratory provides state-of-the-art capability for data visualization, which aids the interpretation of both observational and modeled data and the development of weather briefing tools. NRL-MRY has recently acquired an Origin2000, 128-processor supercomputer, which along with high-performance graphics workstations, network file-servers, and tactical applications systems, is used to conduct numerical weather prediction experiments, process and analyze satellite data, perform simulation studies, and provide demonstrations of tactical weather products. State-of-the-art satellite receiving and processing systems allow local collection of real-time geostationary data globally from four different satellites for applications research in support of the Navy and Joint Typhoon Warning Center operations. This capability has allowed NRL-MRY to take the lead in developing meteorological applications of satellite data for the Navy Satellite Display System-Enhanced (NSDS-E), which is currently being installed at the Navy's regional meteorological/oceanographic (METOC) centers.

Space Science

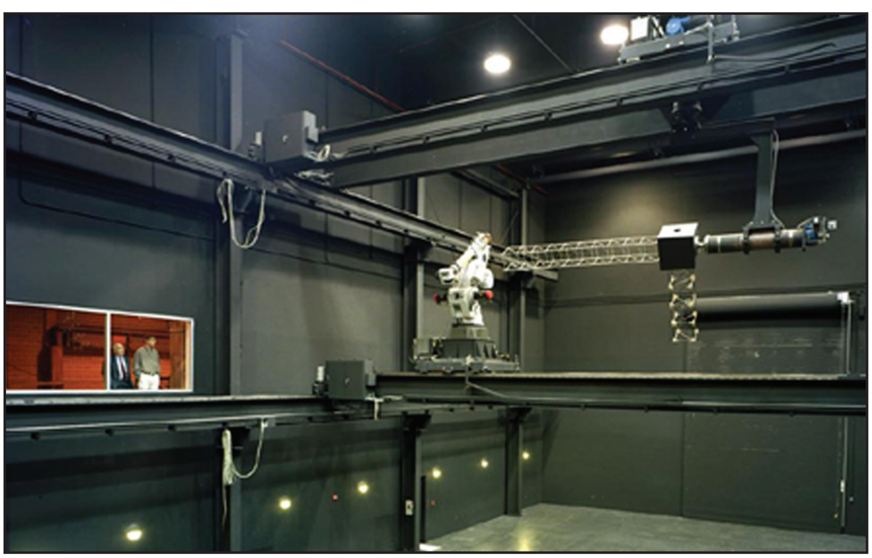
The Space Science Division conducts and supports a number of space experiments in the areas of upper atmospheric, solar, and astronomical research aboard NASA, DOD, and other government-agency space platforms. Division scientists are involved in major research thrusts that include remote sensing of the upper and middle atmospheres, studies of the solar atmosphere, and astronomical radiation ranging from the ultraviolet through gamma rays and high-energy particles. In support of this work, the division maintains facilities to design, construct, assemble, and calibrate space experiments. A network of computers, workstations, image-processing hardware, and special processors is used to analyze and interpret space data. The division's space science data acquisition and analysis efforts include: data analyses of the Oriented Scintillation Spectrometer Experiment (OSSE) for NASA's Compton Observatory; observation of the Sun's interaction with the Earth's upper atmosphere through the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) experiment in support of NASA's Upper Atmosphere Research Satellite (UARS); observation and analysis of solar flares using the Bragg Crystal Spectrometer (BCS) on the Japanese Yohkoh space mission; and observation and analysis of the evolution and structure of the solar corona from the disk to 0.14 AU. This latter effort involves acquiring and analyzing data from the Large-Angle Spectrometric Coronagraph (LASCO) and Extreme Ultraviolet Imaging Telescope (EIT) on the Solar Heliospheric Observatory satellite. In each of these missions, NRL maintains a complete database of spacecraft observations and control over acquisition of data from new observations. These data are available to qualified investigators at DOD and civilian agencies. In addition, the division has a sounding rocket program that affords the possibility of obtaining specific data of high interest and of testing new instrument concepts. These include the general area of high-resolution solar and stellar spectroscopy, extreme ultraviolet imagery of the Sun, and high-resolution, ultraviolet spectral-imaging of the Sun.

In addition, selected celestial and atmospheric targets in the ultraviolet and X-ray bands are observed by three Advanced Research and Global Observation Satellite (ARGOS) experiments—Global Imaging of the Ionosphere (GIMI), High-Resolution Airglow and Auroral Spectroscopy (HIRAAS), and Unconventional Stellar Aspect (USA). ARGOS was successfully launched on February 23, 1999. As part of this program, NRL is establishing collaborative programs to make use of ARGOS data to validate various upper atmosphere models and to study time phenomena in X-ray sources.

Optical calibration facilities, including clean rooms, are maintained to support these activities. These calibration facilities are routinely used by outside groups to support their own calibration requirements.

Space Technology

In its role as a center of excellence for space systems research, the Naval Center for Space Technology (NCST) designs, builds, analyzes, tests, and operates spacecraft as well as identifies and conducts



NRL's Spacecraft Robotics Engineering and Controls Laboratory.

promising research to improve spacecraft and their support systems. NCST facilities that support this work include large and small anechoic radio frequency chambers, clean rooms, shock and vibration facilities, an acoustic reverberation chamber, large and small thermal/vacuum test chambers, a spacecraft robotics engineering and control system interaction laboratory, satellite command and control ground stations, a fuels test facility, and modal analysis test facilities. Also, the Center maintains and operates a number of electrical and electronic development laboratories and fabrication facilities for radio frequency equipment, spacecraft power systems, telemetry, and command and control systems, and includes an electromagnetic interference-electromagnetic compatibility test chamber. NCST has a facility for long-term testing of satellite clock time/frequency standards under thermal/vacuum conditions linked to the Naval Observatory; a 5-m optical bench laser laboratory; and an electro-optical communication research laboratory to conduct research in support of the development of space systems.

RESEARCH SUPPORT FACILITIES

Technical Information Services

The Ruth H. Hooker Research Library offers a full range of traditional library services to support the research program of the Naval Research Laboratory. In addition, it is actively engaged in developing a "digital library" that is available 24-hours-a-day, 7-days-a-week. The single point-of-access to this digital library is the InfoWeb Information System and Gateway (http://infoweb.nrl.navy.mil), which provides desktop access to important scientific databases, such as Science Citation Index Expanded and INSPEC, as well as to reference tools and electronic publications, including more than 2,000 research journals. A key InfoWeb service is TORPEDO *Ultra* v.2, released in October 2001, which hosts several hundred licensed journals and thousands of NRL publications, such as technical reports, journal articles, conference proceedings, and press releases. TORPEDO *Ultra* is the only known system to permit integrated searching, browsing, display, and printing of scientific journals from multiple publishers along with agency publications. The Library's Web-based catalog, locally mounted Science Citation Index Expanded, and an e-mail alerting service called Contents-to-Go, have been enhanced to display the full content of publications that reside in TORPEDO *Ultra*. Links to licensed publications available from Web sites have also been implemented.

Digital sender scans library materials and emails them as PDF attachments.

The Technical Information Services Branch combines publications, graphics, photographic, multimedia, video, and exhibit services into an integrated organization. Publication services include writing, editing, composition, publications consultation and production, and printing management. Quick turnaround black-and-white as well as color copying services are provided. The primary focus is to use digital publishing technology to produce scientific and technical reports that can be used for either print or Web. Graphic support includes technical and scientific illustrations, computer graphics, design services, photographic composites, display panels, sign making, and framing. The NovaJet Pro 600e printer offers exceptional color print quality up to 600 dpi. It produces large-format posters and signs up to 60 inches wide. Lamination and mounting are available. Photographic services include still-camera coverage for data documentation both at NRL and in the field. Photographic images can also be captured with state-of-the-art digital cameras. Photofinishing services provide custom processing and printing of black-and-white and color films. Quick-service color prints are also available. Video services include producing video reports of scientific and technical programs. A video studio and editing facility with high-quality Beta Cam and digital video editing equipment are available to support video production. The NRL Exhibits Program develops and produces displays, audiovisual material, and multimedia programs for presentation at technical meetings, conferences, and symposia. The Multimedia Center uses two complete multimedia systems with Macromedia Director and Adobe Photoshop and a digital video editing system, the AVID Media Composer 1000.

The Administrative Services Branch is responsible for collecting and preserving the documents that comprise NRL's corporate memory. Archival documents include personal papers and correspondence, laboratory notebooks, and work project files—documents that are appraised for their historical or informational value and considered to be permanently valuable. The branch provides records management services, training, and support for the maintenance of active records, including electronic records and e-mail, as an important information resource. The Administrative Services Branch is also responsible for NRL's postal mail services and NRL's Forms and Reports management programs (including electronic forms). The Administrative Services Branch also compiles and publishes the NRL Code Directory and Organizational Index and provides NRL Locator service.

FIELD STATIONS

NRL has acquired or made arrangements over the years to use a number of major sites and facilities for research. The largest facility is located at the Stennis Space Center (NRL-SSC), in Bay St. Louis, Mississippi. Others include a facility at the Naval Postgraduate School in Monterey, California (NRL-MRY), and the Chesapeake Bay Detachment (CBD) in Maryland. Additional sites are located in Maryland, Virginia, Alabama, and Florida.

Flight Support Detachment (NRL FSD)

Located at the Naval Air Station Patuxent River, Lexington Park, Maryland, the Flight Support Detachment (NRL FSD) is manned by approximately 9 officers, 80 enlisted, four civilians, and 20 contract maintenance technicians. NRL FSD is currently responsible for the maintenance and security of five uniquely configured P-3 Orion turboprop research aircraft. The FSD conducts numerous single-aircraft deployments around the world in support of a wide range of scientific research projects.

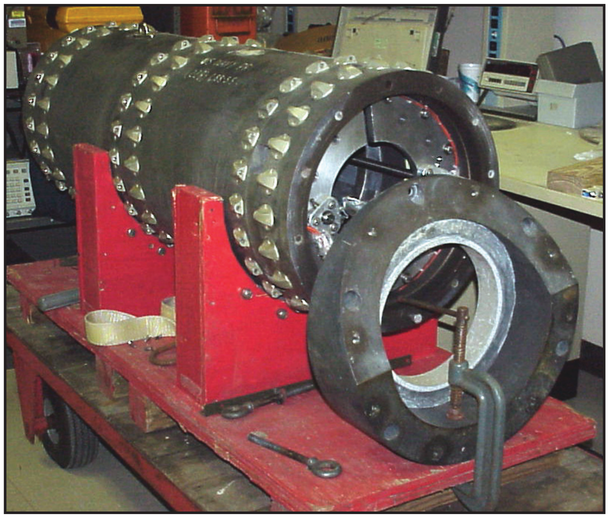
In FY 01, NRL FSD provided flight support for diverse research programs including: Advanced Radar Periscope Detection and Discrimination (ARPDD), an advanced variant of the AN/APS-137 ISAR radar used for detecting submarine periscopes; Cooperative Engagement Capability (CEC), an airborne suite to test USN Aegis Cruiser systems; Airborne Geographical Sensor Suite (AGSS), involving data and gravimeter testing to detect variations in the ocean floor; Integrated Electronic Warfare System (IEWS), a system that simulates radar of various surface and airborne platforms; Shared Reconnaissance Pod System (SHARPS), a follow-on upgrade to the TARPS System; and NAVOCEANO Oceanographic Surveillance (OS).

The Flight Support Detachment flew over 1,500 total hours in FY 01. The FSD was recognized for its excellent safety record by the Chief of Naval Operations as the winner of the Research, Development, Test and Evaluation Wing's Safety "S" award for CY 00. NRL FSD's flight safety record spans over 39 years and includes over 60,000 mishap free flight hours.

Chesapeake Bay Detachment (CBD)

CBD occupies a 168-acre site near Chesapeake Beach, Maryland, and provides facilities and support services for research in radar, electronic warfare, optical devices, materials, communications, and fire research. A ship-motion simulator (SMS) is used to test and evaluate radar, satellite communications, and line-of-sight RF communications systems under dynamic conditions (various sea states). The SMS can handle up to 12,000 pounds of electronic systems. A roll motion of up to 30 degrees (15 degrees to port and 15 degrees to starboard) can be applied to this axis. The pitch axis has a fixed motion of 10 degrees (5 degrees to stern and 5 degrees to bow). Periods along both axes, pitch and roll, are variable—from a slow 32-s to a brisk 4-s rate. Variable azimuth motion can also be added to the pitch and roll action. Synchronized positioning information (×1 and

Researcher 589 takes off from an overseas airbase in support of the IEWS project.



An instrumented mine is equipped with data recording devices to record currents, sediment density, salinity, and many other environmental parameters. The mine is placed on the seafloor, simulating a real mine. Light sensors record how far the mine buries into the sediment.

×36) is available for each of the three axes of the SMS.

Because of its location high above the western shore of the Chesapeake Bay, unique experiments can be performed in conjunction with the Tilghman Island site, 16 km across the bay from CBD. Some of these experiments include low clutter and generally low-background radar measurements. By using CBD's support vessels, experiments are performed that involve dispensing chaff over water and radar target characterizations of aircraft and ships. Basic research is also conducted in radar antenna properties, testing of radar remote-sensing concepts, use of radar to sense ocean waves, and laser propagation. CBD also hosts facilities of the Navy Technology Center for Safety and Survivability, which conducts fire research on simulated carrier, surface, and submarine platforms.

Stennis Space Center (NRL-SSC)

NRL-SSC, a tenant activity at NASA's John C. Stennis Space Center, is located in the southwest corner of Mississippi, about 50 miles northeast of New Orleans, Louisiana, and 20 miles from the Mississippi Gulf Coast. Other Navy tenants at SSC include the Commander, Naval Meteorology and Oceanography Command and the Naval Oceanographic Office, who are major operational users of the oceanographic and atmospheric research and development performed by NRL. The Naval Oceanographic Office provides access for NRL researchers to one of the Navy's largest supercomputers. This unique concentration of operational and research oceanographers makes SSC the center of naval oceanography and the largest such groupings in the Western world. Additional Navy tenants at SSC include Special Boat Unit 22, the Human Resources Service Center South East, and the Navy Small Craft Instruction and Training Service.

NRL-SSC provides administrative and business operations for entities of the Acoustics, Marine Geosciences, and Oceanography Divisions. NRL-SSC occupies more than 175,000 square feet of research, computation, laboratory, administrative, and warehouse space. Facilities include the Electron Microscopy Facility, an oceanographic visualization center, numerous large antennas to receive available oceanographic and meteorological satellite data, an electrochemistry laboratory, unique oceanographic and geotechnical laboratories, the Map Data Formatting Facility, the Tactical Oceanography Simulation Laboratory with TOWAN databases, and numerous laboratories for acoustic and oceanographic computation, instrumentation, analysis, and testing. Special areas are available for constructing, staging, refurbishing, and storing seagoing equipment.

Marine Meteorology Division (NRL-MRY)

NRL's Marine Meteorology Division (NRL-MRY) is located in Monterey, California, on the grounds of the Naval Postgraduate School (NPS) Annex, which is about a mile from the NPS main campus. As a tenant activity of the Naval Support Activity, Monterey Bay, the NRL facility is collocated with the Navy's operational Fleet Numerical Meteorology and Oceanography Center (FNMOC) and with a NOAA National Weather Service Forecast Office (NWSFO). The NPS Annex campus, which covers approximately five acres, comprises four primary buildings—one occupied exclusively by NOAA, one that houses both the NRL and FNMOC supercomputer/operational facilities, and two large buildings containing office space, computer laboratories, and conference facilities that are shared by FNMOC and NRL-MRY personnel. The site also provides warehouse space and recreational facilities. NRL-MRY occupies approximately 30,000 square feet in shared buildings. This includes not only office space, but also a small library, the John B. Hovermale Visualization Laboratory, the Bergen Data Center, the Geostationary Satellite Processing Facility, and space for the hardware supporting the Tactical Environmental Support System (TESS), the Tactical Atmospheric Modeling System/Real-Time (TAMS/RT), and the Master Environmental Laboratory.

NRL-MRY is dedicated to advancing fundamental scientific understanding of the atmosphere, including the air-sea interface, and to applying those scientific discoveries in the development of innovative objective weather prediction systems. FNMOC is the Navy's central site facility for the production and distribution of numerical weather prediction products in support of Navy operations around the globe, as well as to other defense-related activities. Fleet Numerical and the Navy's regional METOC Centers are the primary customers for the numerical weather prediction systems that are developed by NRL-MRY. This collocation of the scientific developer with the operational customer offers advantages for the successful implementation of new systems and system upgrades, and for the rapid infusion of new research results from the community at large. NRL-MRY has efficient access to FNMOC's large classified vector supercomputer and other systems. This allows advanced development to take place using the real-time on-site global atmospheric and oceanographic databases. Collocation also offers the opportunity for FNMOC scientists to team with NRL-MRY scientists during the transition and implementation process, and NRL-MRY scientists remain readily available for consultation on any future problems that arise.

NRL-MRY benefits from the opportunities provided by NPS for continuing education and collaborative research with the Department of Meteorology and Oceanography.

Midway Research Center

The Midway Research Center (MRC) is located on a 158-acre site in Stafford County, Virginia. Located adjacent to the Quantico Marine Corps' Combat Development Command, the MRC has 10,000 square feet of operations and administration area and three precision 18.5-m-diameter parabolic antennas housed in 100-ft radomes. The MRC, under the auspices of the Naval Center for Space Technology, provides NRL with state-of-the-art facilities dedicated solely to space-related applications in naval communications, navigation, and basic research.

Research Platforms

Mobile research platforms contribute greatly to NRL's research. These include six P-3 Orion turboprop aircraft and one ship, the ex-USS *Shadwell* (LSD-15), berthed in Mobile Bay, Alabama. The ex-*Shadwell* is used for research on aboard ship fire-suppression techniques.

LOOKING AHEAD

To provide preeminent research for tomorrow's Navy, NRL must maintain and upgrade its scientific and technological equipment to keep it at the forefront of modern research facilities. The physical plant to house this equipment must also be state of the art. NRL has embarked on a Corporate Facilities Plan to accomplish these goals. This plan and future facility plans are described below.

THE CORPORATE FACILITIES INVESTMENT PLAN (CFIP)

The CFIP is a capital investment plan that uses both Congressionally approved military construction (MILCON) and Laboratory overhead funds to provide modern, up-to-date laboratory facilities for NRL. Past MILCON projects have included the Electro-Optics Building at NRL-DC and a new Ocean Acoustics Research Laboratory at NRL-SSC. Future MILCON projects include an already approved Nano-Science Research Laboratory in FY 01 and a proposed Autonomous Vehicles Research Building in the FY 03 time frame.

To complement these efforts, overhead funds have been used to renovate and upgrade laboratory and support areas in several existing buildings. Modern laboratory facilities have recently been provided for the Center for Bio/Molecular Science and Engineering, the Materials Science and Technology Division, the Remote Sensing Division, the Acoustics Division, the Information Technology Division, and the Radar Division.

In parallel with efforts to upgrade laboratory buildings to the most modern standards, those buildings that were built during World War II and do not lend themselves to renovation are being demolished. This will provide space for the construction of future MILCON buildings, and it will also reduce the Laboratory's overhead costs.

Information Technology

The Information Technology Division's Center for Computational Science (CCS) operates scalable, massively parallel Global Shared Memory (GSM) computer systems, including a 128-processor SGI Origin3800 with cache-coherent Non-Uniform Memory Access (ccNUMA) architecture. Plans for FY 02 include the addition of an experimental multi-threaded architecture (MTA) high-performance computer with 32 or more processors and the replacement of existing Sun HPC Cache-Only Memory Access (COMA) architecture with next generation SUN machines in early FY 02. These systems comprise the Distributed Center (DC) at NRL whose hardware is funded by the DOD High Performance Computing Modernization Program (HPCMP). The systems are used in the innovative exploration and evaluation of MPP technology for the solution of significant militarily relevant problems relating to computational and information science. The systems allow for leading-edge research in support of heterogeneous parallel processing applications by the Navy and DOD science and technology communities.

Chemistry

The revolutionary opportunities available in nanoscience/nanotechnology have led to a National Nanotechnology Initiative. NRL has been a major contributor to progress to date, but has been hampered by inadequate infrastructure. The manipulation and measurement of materials with nanometer dimensions is very difficult. One must be able to reliably and precisely locate structures with nanometer dimensions in much larger areas. Furthermore, the measurement of nanostructure properties is difficult simply because there are not many atoms/molecules present. A building designed for nanoscience must be carefully constructed to minimize potential sources of "noise." Vibrations, thermal drift, and humidity drift can cause major problems in positioning a tool. Good signal-to-noise ratio requires electromagnetic and acoustic interference-free environments. Airborne contamination can readily cover over a nanostructure. NRL has a commitment of FY 01 MILCON funds to design and build a special nanoscience laboratory that will minimize these "noise" sources. Construction is scheduled for completion by 2003.

Plasma Physics

The Plasma Physics Division has set up a Large Area Plasma Processing System (LAPPS) facility to investigate a new technique to produce plasmas for plasma processing. Applications include production of large-area flat-screen displays or elements for phased arrays or materials modification such as surface polymerization or ion implantation. The system is based on low-energy electron beam ionization of a background gas to produce the desired plasma. The system may have advantages over existing techniques for production of large-area (square meter) plasmas, efficiency of plasma production, and control of reactive species.

Electronics Science and Technology

Important division emphasis is focused on the continual upgrading of the Nanoprocessing Facility (NPF) and the Compound Semiconductor Processing Facility (CSPF) and expanding activities in the nanoelectronics, wafer bonding, heterostructures, and vacuum electronics science and technology programs. The NPF has added a second dicing saw to give additional capability in the assembly area. The MOCVD Facility will install an updated computer control capability for the growth of complex structures. The EPICENTER (a joint activity of the Electronics Science and Technology, Materials Science and Technology, Optical Science, and Chemistry Divisions) has installed an additional III-V material molecular beam epitaxial machine. These facilities are enhanced by the new Joint Laboratory for Proximal Probe Nanofabrication that serves as a resource for characterization patterning and process definition necessary for advanced nanodevice fabrication, and the new Wafer Bonding Laboratory that establishes novel substrates for epitaxial growth and wafer bonding for two-sided power switching devices.

Ocean Research Laboratory

NRL's Ocean Research Laboratory is a 52,000 square-foot building that houses the Oceanography Division of the Ocean and Atmospheric Science and Technology Directorate. The building contains office space, oceanographic laboratories, staging areas, a small machine shop, electronic and secure laboratories, and visualization and computing facilities for research and development in ocean science and remote sensing.

Acoustics

NRL's Salt Water Tank Facility is designed to provide a controlled environment for studying complex bubble-related processes found in the ocean. It is an experimental pool facility for studies of underwater acoustics, fluid dynamics, and air-sea interface environmental topics under saline conditions. This facility is currently being used to study the acoustics of bubbly media, including bubble entrainment and ambient noise generation, scattering from bubbly structures, and propagation through bubbly media. Future studies include the interaction of bubbles with turbulent fluid flows, bubble coalescence and dissolution, effects of surfactants and contaminants, and bubble-related gas exchange across the air-sea interface.

Remote Sensing

The Remote Sensing Division has developed and installed 74 MHz receivers on the National Radio Astronomy Observatory's Very Large Array (VLA), thereby producing the world's highest angular resolution and most sensitive astronomical interferometric array operating below 150 MHz. In contrast to the VLA's maximum baseline of 35 km, all previous astronomical interferometers operating below 150 MHz had baselines less than 5 km because ionospheric structure had been thought to impose phase variations that would corrupt the interferometric imaging. Work in the Remote Sensing Division has shown that radio astronomical techniques can now remove the ionospheric phase variations and extend interferometer baselines to arbitrary lengths. In its first year of operation, the NRL/NRAO 74 MHz system has been used for a variety of innovative observations with encouraging initial results in solar system, Galactic, and extragalactic astrophysics. The success of the NRL/NRAO 74 MHz system indicates that it is possible to open a new high-resolution, high-sensitivity astronomical window by going to an even larger, more sensitive system. The Remote Sensing Division, in collaboration with the Netherlands Foundation for Research in Astronomy, is currently designing a follow-on instrument, the Low Frequency Array (LOFAR). LOFAR will be a fully electronic, broadband array operating in the 15 to 150 MHz range, with a collecting area of 1 square km at 15 MHz and a maximum baseline of 500 km resolution and sensitivity over the state of the art.

The Remote Sensing Division is also developing other new facilities-class sensors including the Navy Ultrawideband Synthetic Aperture Radar (NUSAR). NUSAR is a fully capable high-resolution (less than 1 meter impulse response) synthetic aperture radar system made to be operated from light aircraft. It is fully polarimetric and can operate as an along-track interferometer. Its frequency range will be expandable, and ultimately it will operate from VHF to X-band.

Marine Geosciences

The Marine Geosciences Division has greatly enhanced the capabilities and quality of seafloor sediment fabric analyses through completion of installation and staff training for its 300-kV transmission electron microscope (TEM) and accompanying environmental cell (EC). The TEM-EC is housed in a specially built facility imparting a null effect on the functioning of the TEM-EC electronics. The new facility will improve transition of developed capabilities and sediment fabric understanding to applied issues of acoustic and shock-wave propagation, mine burial, and mine countermeasures.

Vacuum Ultraviolet Space Instrument Test Facility

The Space Science Division facilities include an ultraclean solar instrument test facility in Building A-13 on the main NRL campus. The new facility is designed to satisfy the rigorous contamination requirements of state-of-the-art solar spaceflight instruments. The facility has a 400-ft^2 Class 10 clean room and a large Solar Coronagraph Optical Test Chamber (SCOTCH). This completely dry-pumped, 550-ft^3 vacuum chamber is maintained at synchrotron levels of cleanliness. Solar instrumentation up to 1 m in diameter and 5 m in length can be physically accommodated in the chamber. The instrument's optical performance is probed and calibrated with a variety of visible and XUV sources mounted on the chamber's 11-m beamline. The optical testing and characterization of the Large-Angle Spectrometric Coronagraph (LASCO) instrument for the European Space Agency's Solar Heliospheric Observatory satellite were conducted in this chamber. Coronagraph straylight characterization was carried out by mounting a set of baffles in the main beamline, illuminating the instrument with a simulated solar beam, and measuring the residual radiation. A stray light background measurement of 10^{-12} was successfully measured in the LASCO C3 channel. Coronagraph calibration was carried out by installing back-illuminated calibrated opals in front of the instrument entrance aperture. Instrument polarization properties were analyzed by using a variety of polarizers installed in a wheel located between the opal and the instrument. The wheel was remotely controlled from outside the chamber. Instrument Mueller matrices were verified with a 12-in. diameter, two-plate partial polarizer. Calibration and focus of XUV solar instrumentation are accomplished by exposing the instrument to an XUV windowless collimator at the end of the tank. The facility also has a small thermal bake/vacuum test chamber used for vacuum conditioning and thermal testing of spaceflight components and subassemblies. Both the SCOTCH and the small test chamber are instrumented with temperature-controlled quartz-crystal monitors and residual gas analyzers for real-time, quantitative measurements of volatile contamination.

REHABILITATION OF SCIENTIFIC FACILITIES

Specialized facilities are being installed or upgraded in several of the research and support divisions.

Flight Support Detachment

NRL's Flight Support Detachment (FSD) has continued to improve both capabilities and diversity among its aircraft platforms. Aircraft 153442 has undergone extensive modifications with Lockheed Martin to install a "rotodome" antenna and full AEW radar system. The aircraft is currently supporting the Navy's Theater Air Defense programs and providing a testbed for advanced EW radar research. Additionally, all aircraft have completed extensive bomb-bay design improvements that will allow the aircraft to carry more diverse scientific payloads. Aircraft 158227's communications capabilities were significantly upgraded with a state-of-the-art satellite telephone; aircraft 154589 is next in line to receive this INMARSAT system. These upgrades and modifications will ensure that NRL will have the finest airborne research capabilities well into this century.

Radar

About 75% of the Radar Division moved into the newly renovated Building 60 quarters in January 2000. The remainder of the division will occupy the adjacent Building 42 when the renovation is complete in about 2002. The "High Bay" facility in Building 48 is scheduled to be replaced by a newer facility to be built in Building 71.

Information Technology

The Information Technology Division continues to transition stable technology from high-performance network testbed activities into the NRL local area network. This effort includes support of ATM technology at stream rates of 622 Mbps (OC12c) and 2.5 Gbps (OC48) across the enterprise with demonstrations and technology integration to allow first use of 10 Gbps single streams and higher. The current computing architectures, the SGI Origin3800 and the Sun Ultra, are continuously undergoing upgrade and evaluation of both hardware and software. The NRL CCS works closely with the DOD HPC community and the HPC vendors to provide insight, balance, and value-added capabilities within the MPP testbed infrastructure.

Materials Science and Technology

Renovation of Building 3 has been completed. The building is composed of two of the original five buildings at NRL and contains modern laboratories for studies of thin-film deposition and characterization, superconducting materials, magnetic materials, and other materials science projects. The new space features the most modern molecular beam epitaxy and other materials synthesis and processing equipment, an up-to-date fatigue and fracture laboratory, and state-of-the-art diagnostic equipment, including electron microscopes, spectrometers, and electron and X-ray diffraction equipment. The newly renovated building also contains office and laboratory space for approximately 70 technical personnel.

Plasma Physics

A state-of-the-art short-pulse (0.4 ps), high-intensity Table-Top Terawatt (T^3) laser currently operates at 10 TW and 2×10^{19} W/cm^2 for a variety of physics studies. The T^3 laser will be upgraded to boost its power to 25 TW and intensities to $>10^{19}$ W/cm^2. This will provide a facility to do fundamental physics experiments in intense laser-plasma interactions, intense laser-electron beam interactions, and intense laser-matter interactions.

The division is building a repetitively pulsed (5 pps) krypton fluoride (KrF) laser called Electra. Electra will develop the technologies needed for inertial fusion energy (IFE). A laser for a power plant would have to fire five times per second, run for several years, and meet stringent cost and efficiency requirements. Electra will develop the technologies that can meet these requirements. It will have a laser output of around 400 to 700 Joules. The size of Electra was chosen to be large enough to be scalable to a power plant size, but small enough to be flexible.

Electronics Science and Technology

The Electronics Science and Technology Division continues to upgrade and expand its capability in nanofabrication science. Facilities will be enhanced with new laboratories and an expanded EPICENTER that includes a new vacuum processing chamber and two new epitaxial growth chambers. The Ultrafast Laser Facility and the Space Solar Cell Characterization Laboratory are being moved into Building 208 from Buildings 65/75 to provide additional capabilities. The newest laboratories that are adding equipment are the Laboratory for Proximal Probe Nanofabrication (LPPN), which will explore the limits of nanolithography with proximal probes; the Laboratory for Advanced Materials Processing (LAMP), which will explore the chemistry and physics of processes used routinely in the formation of modern devices and extend these processes into the nanoscale fabrication range; and the Wafer Bonding Laboratory, which will establish the wafer bonding technology needed for two-sided power switching devices.

Center for Bio/Molecular Science and Engineering

Construction is currently underway to renovate and modernize all office and laboratory spaces in Building 42. When complete, Code 6900 will occupy new molecular biology and biochemistry laboratories in approximately one half of the building.